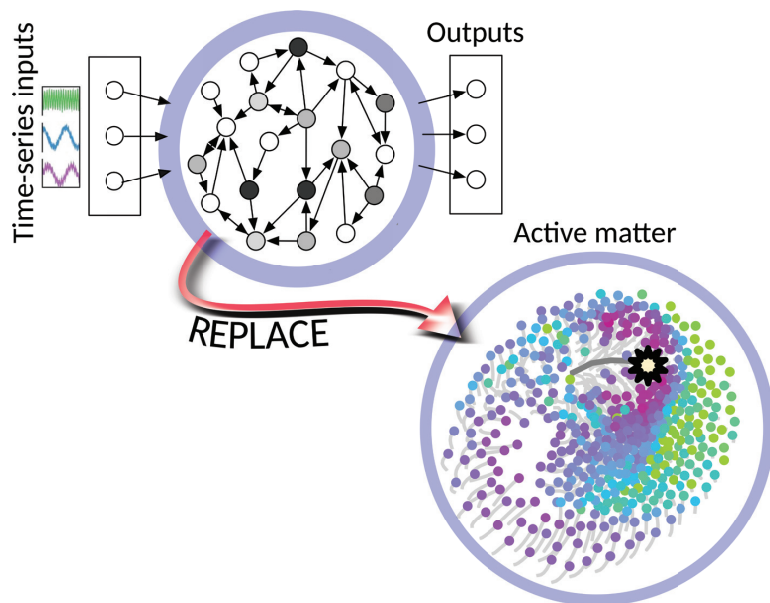


<https://uni-due.zoom-x.de/j/64228670246?pwd=RjVQeFNIUkRKkRkpiNVpKYXhJaFNLdz09> (gilt für alle Vorträge)

How Nonequilibrium Statistical Physics Helps Open The Black Box of AI and Future Computing

Dr. Miriam Klopotek, Stuttgart Center for Simulation Science, SimTech Cluster of Excellence



Artificial intelligence (AI) technologies are permeating all sectors of society, including science. But their ‘black-box’ character poses many problems, and running AI models consumes huge amounts of energy. At a fundamental level, computation emerges from complex physical systems driven out of thermodynamic equilibrium. Physical computing methods, such as reservoir computing (RC)—where materials themselves process information—allow us to use a material’s direct response to input signals for prediction. Using a visual example of RC that exploits the dynamics of an active-matter (simulated) model, we try to shed light on the origins of inference: for example, in the nature of correlated dynamics or, phenomenologically, the abilities of the material to both self-heal and respond elastically [1]. Predictive performance is also deeply tied to the irreversibility of the physical dynamics, as the computation must produce entropy in line with the Second Law [2]. Regarding conventional AI methods, artificial neural networks can learn representations of physical data that mirror physical concepts [3]. The learning process can mimic self-organization. Thus, a loop can be closed between physical dynamics, the learning machines, and human understanding. We offer some perspectives on unconventional computing born from fusions of physical systems with AI.

[1] M. U. Gaimann and M. Klopotek, arXiv:2505.05420 (v4: Jan 2026) and [arXiv:2509.01799 (v2: Mar 2026)].

[2] P. Egenlauf, ... , and M. Klopotek, arXiv:2607.29434 (Jul 2026).

[3] M. Weinmann and M. Klopotek, arXiv:2607.10285, (Jul 2026).